THE EFFECT OF BLADE LEAN ON AN AXIAL TURBINE STATOR FLOW HAVING VARIOUS HUB TIP RATIOS

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ABSTRACT

The effect of simple lean on an axial turbine stator was examined using a threedimensional viscous flow code. A constant section stator with no meridional contouring was chosen to isolate the effect of the lean. Four different lean angles were examined at three hub/tip ratios.

INTRODUCTION

Blade lean has been utilized by turbine designers to alter the radial pressure gradient of stator and rotor flows. Leaning has been used to increase blade reaction at the hub of low pressure ratio blades (Denton, 1987, 1989; Shikano, et al, 1990). In the previous studies, the stator sections have had varying geometry sections from hub to tip, as well as unique stacking schemes. Additionally, the sections previously analyzed have had contoured meridional passages. In order to isolate the effect of lean, a constant section stator was designed at a specific meanline radius (35.56 cm). The stator section at meanline radius is illustrated in Figure 1. Four different lean angles (5, 10, 15, and 20 degrees) will be employed at three different hub/tip ratios corresponding to stator heights equal to 2.54 cm, 12.7 cm, and 25.4 cm, respectively. The lean used is simple, the tip section is inclined toward the pressure side of the stator. The results of the analyses of the leaned stator configurations will then be compared to the zero degree leaned stator configuration at each hub/tip ratio.

The Dawes BTOB3D three-dimensional viscous code was used to perform all analyses. The code solves the Reynolds averaged Navier Stokes equations in finite volume form. The Dawes code uses the Baldwin-Lomax mixing length turbulence model. The reader is referred to Dawes (1986, 1987, and 1988) for more information on the particulars of the three-dimensional code. This particular code was chosen by the author because of its robustness and stability. It is widely used in the turbomachinery industry (Dawes 1988; Casey, et al, 1990).

A coarse grid comprised of 26,300 nodes was used for each configuration in this study. The next phase of this study will involve the use of finer grids. Figure 2 shows the blade to blade mesh at the meanline radius. Figures 3 and 4 show the stator exit quasiorthogonal meshes of the zero and twenty degree leaned configurations for the 0.697 hub/tip ratio examination.

The gas that was simulated in these analyses was common air. This was chosen to permit experimental verification in the future.

The procedure used in this study was quite simple; at each hub/tip ratio, the mass flows of the leaned stator configurations were matched to the mass flow of the zero degree leaned stator. The three-dimensional results were mass averaged, so that certain quantities could be compared.

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Additionally, certain contour comparisons were made. All pertinent geometric and thermodynamic quantities used in this study are provided in Table I.

RESULTS

Hub/Tit) Ratio = 0.931 (2.54 cm Stator Height)

The mass averaged Mach number distribution at the stator exit is shown in Figure 5. There is virtually no difference between the zero and five degree lean stators. As the lean angle increases, there is a uniform reduction in Mach number. The mass averaged exit meridional and exit tangential velocity distributions are shown in Figures 6 and 7.

Both the meridional velocity and the tangential velocity are reduced through the entire span with increased lean angle. The mass averaged exit flow angle is shown in Figure 8. All cases converged at the meanline radius. Increased lean angle reduces the exit flow angle from 0 to 50 percent span, while it increases the exit flow angle at the tip section (100 percent span).

Figures 9 and 10 show the stator exit Mach number contour plot for the zero and twenty degree lean angle configurations.

Hub/Tip Ratio = 0.697 (12.7 cm Stator Height)

The mass averaged exit Mach number distribution is shown in Figure 11. As with the previous hub/tip ratio, there is virtually no difference between the zero and five degree lean angle configurations. As the lean angle is increased, there is a uniform reduction in Mach number.

The mass averaged exit meridional velocity and exit tangential velocity distributions are shown in Figures 12 and 13. With the exception of the twenty degree lean angle configuration, the meridional velocity distributions are uniform from 0 to 50 percent span. As the lean angle is increased, the meridional velocity is steadily decreased from 50 to 100 percent span. As with the Mach number distribution, the zero and five degree lean angle configurations are uniform. The tangential velocity is reduced from hub to tip with increased lean angle.

The mass averaged exit flow angle is shown in Figure 14. Increased lean angle reduces **the exit flow angle** from 0 to 90 percent span. From 90 to 100 percent span increased lean angle increases the exit flow angle.

Figures 15 and 16 show the stator exit Mach number contour plot for the zero and twenty degree lean angle configurations.

Hub/Tip Ratio = 0.474 (25.4 cm Stator Height)

The mass averaged exit Mach number distribution is shown in Figure 17. As with the two previous cases, there is no difference between the zero and five degree lean angle configurations. Increased lean angle uniformly reduces the exit Mach number.

The mass averaged exit meridional velocity and exit tangential velocity distributions are shown in Figures 18 and 19. Increased lean angle increases meridional velocity up to 75 percent span. From 75 percent to 100 percent span, increased lean angle reduces the meridional velocity. As with the pervious two cases, there is no difference in tangential velocity **between the** zero and five degree lean angle configurations. Increased lean angle uniformity reduces the tangential velocity at the exit.

The mass averaged exit flow angle is shown in Figure 20. Increased lean angle reduces the exit flow angle up to approximately 92.5 percent span. Increased lean angle increases the exit flow angle from 92.5 percent to 100 percent span.

The stator exit Mach number contour plots for the zero and twenty degree lean angle configurations are shown in Figures 21 and 22, respectively.

CONCLUSIONS

Simple lean has been shown to have an impact on the exit flow field of an axial stator. Even high values of hub/tip ratio are affected by the lean, provided lean angle is greater than five degrees.

The effect of lean angle on the exit flow angle of the stator demonstrates its value to axial turbine design. The designer can use lean in conjunction with blade twist to modify blade reaction and rotor work distribution.

The next phase of this investigation is to proceed with a fine grid analysis of the previous configurations, and then proceed with an experimental investigation. Additional simple and compound lean angle distributions will also be investigated.

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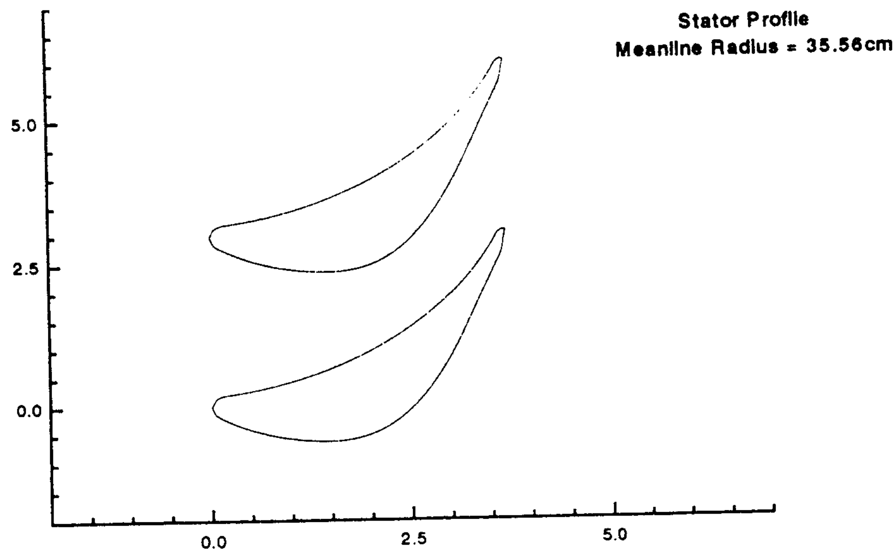

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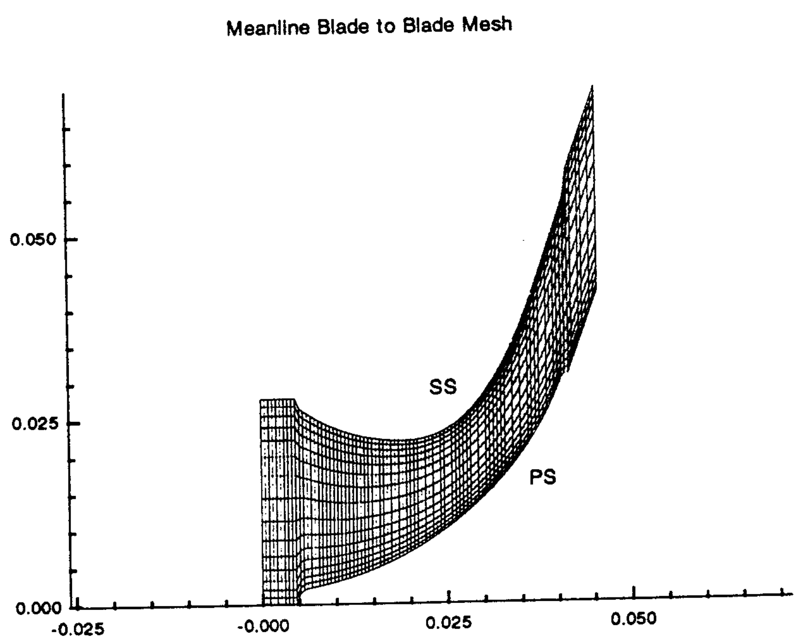

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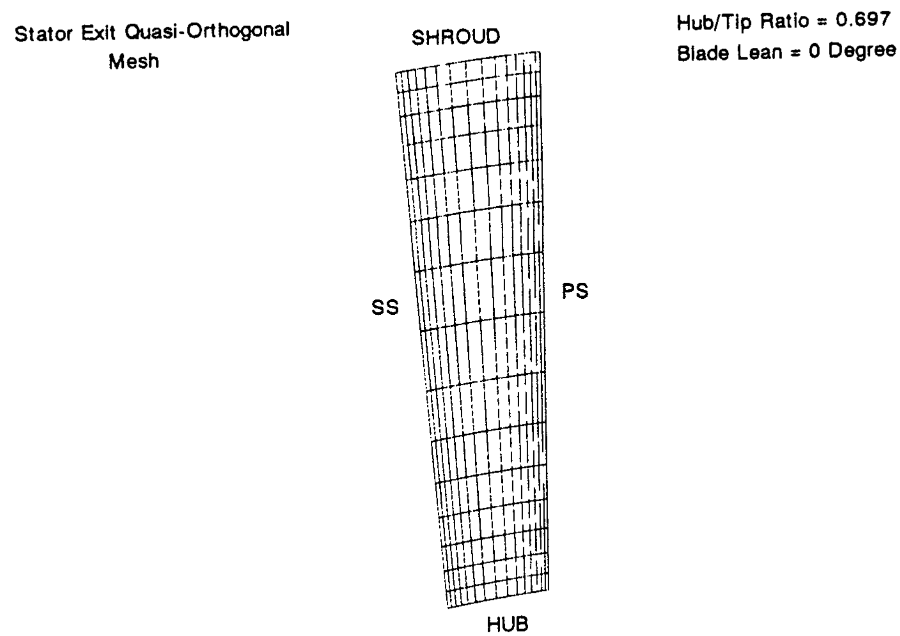

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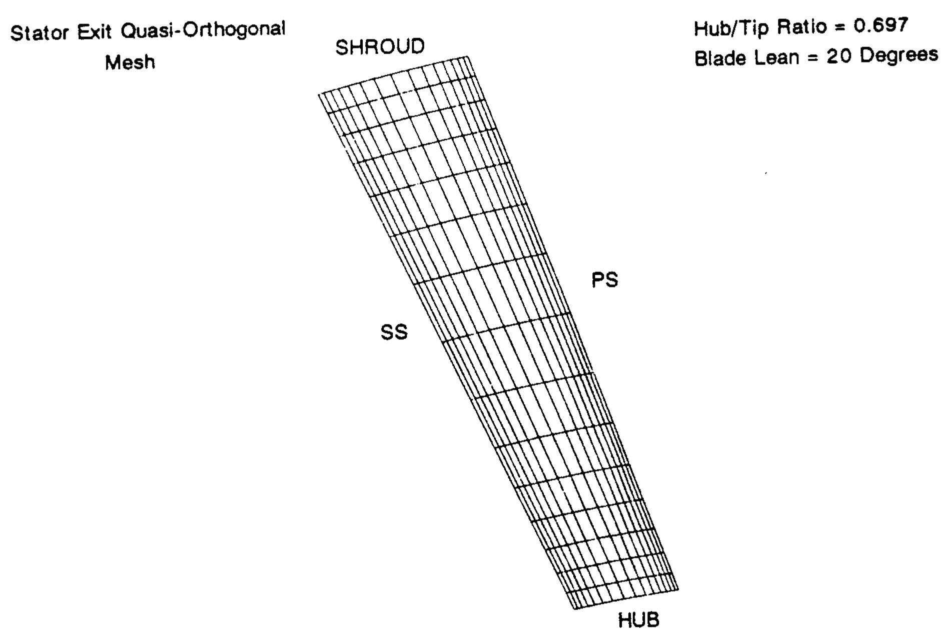

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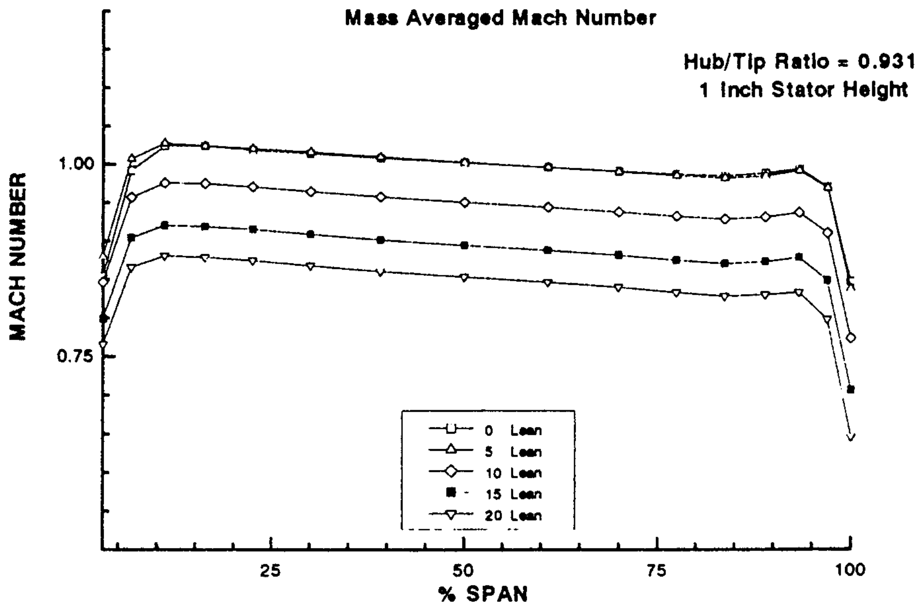

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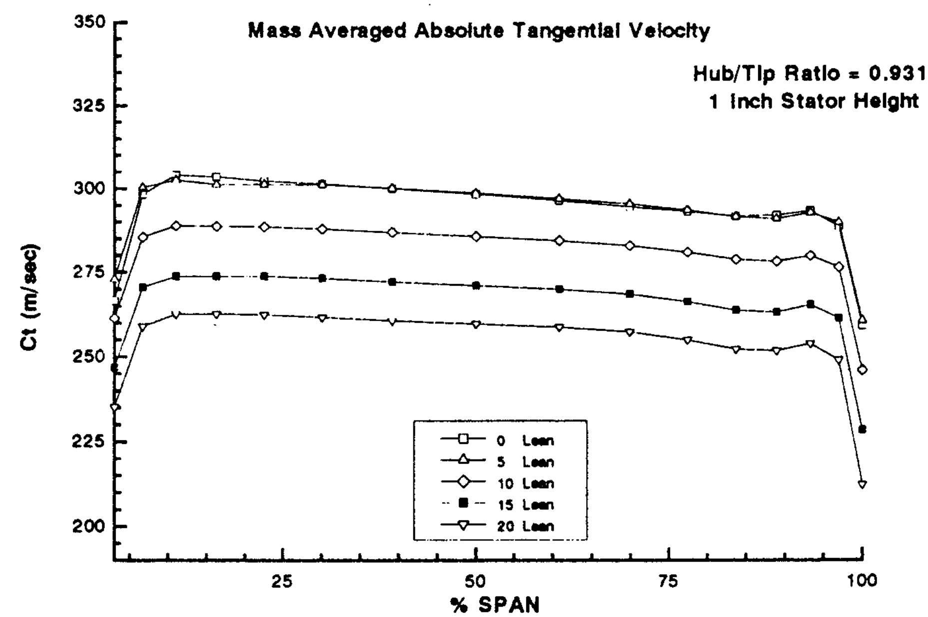

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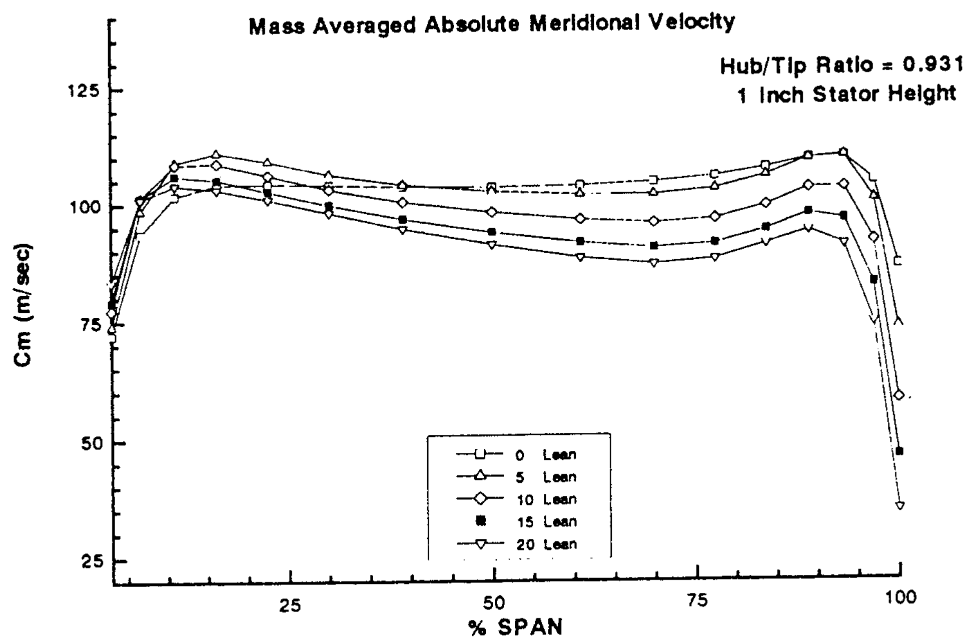

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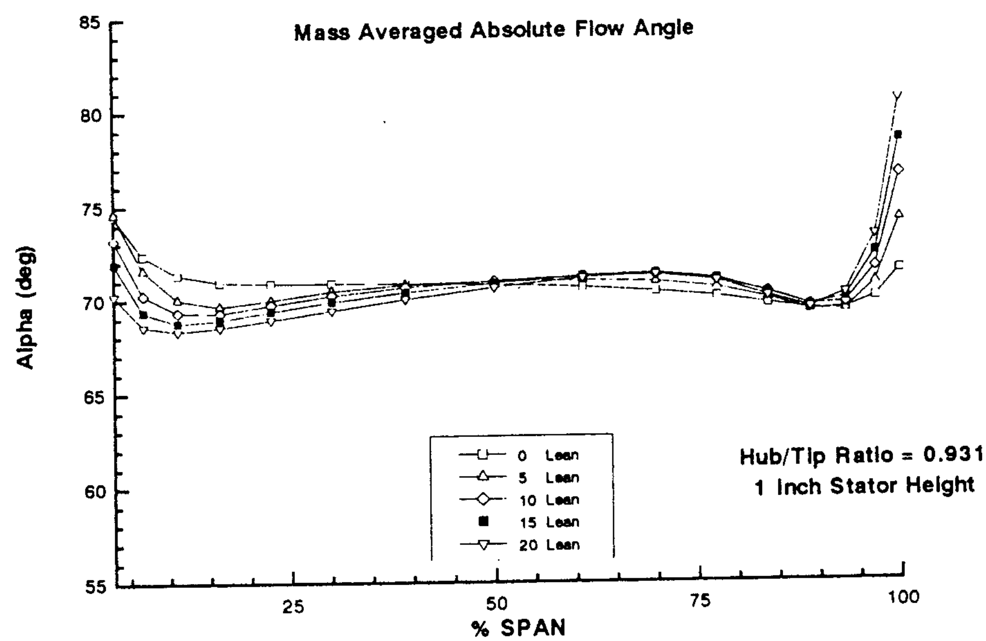

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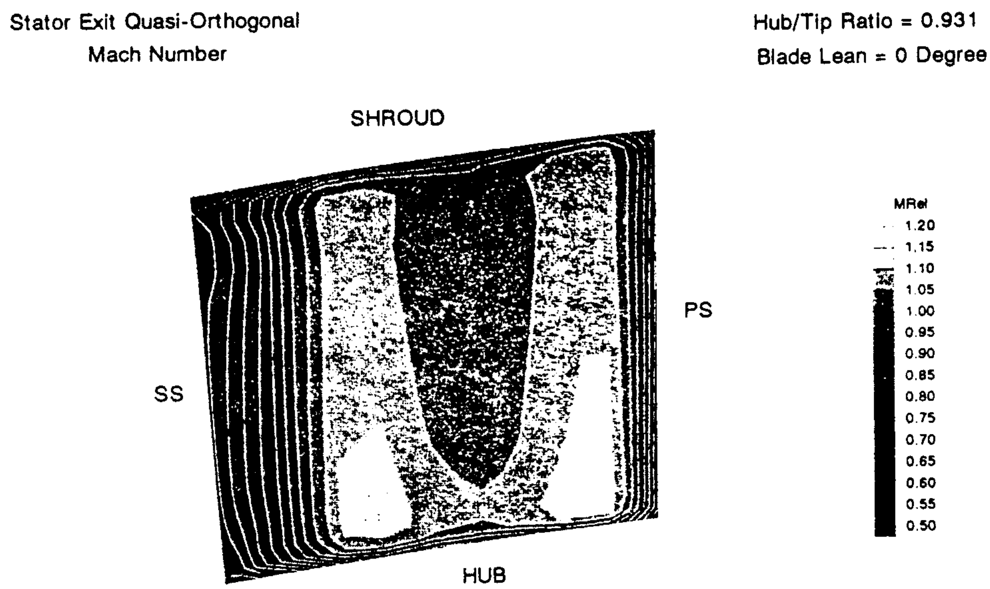

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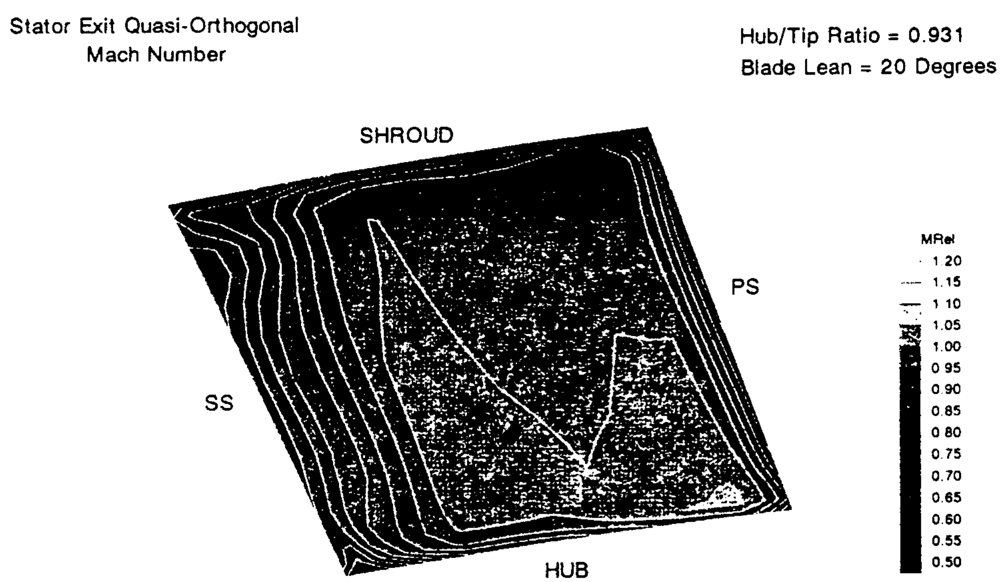

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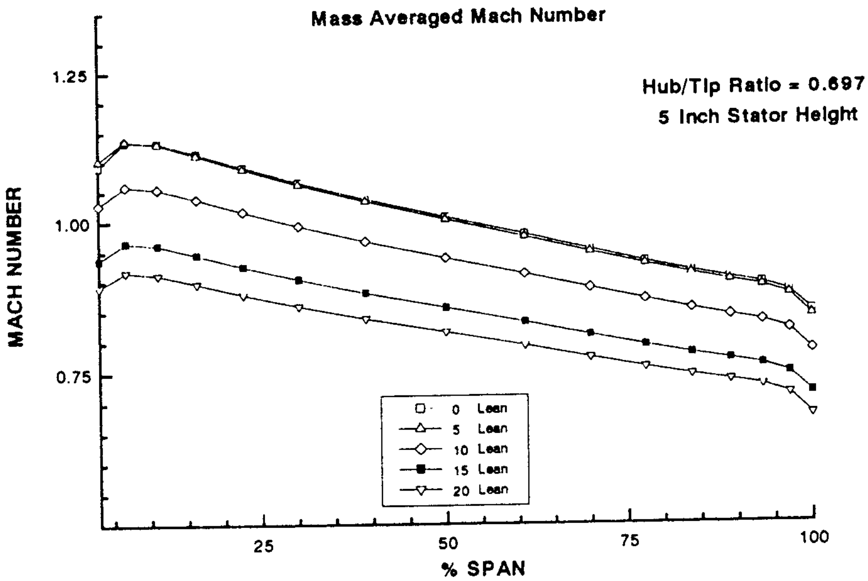

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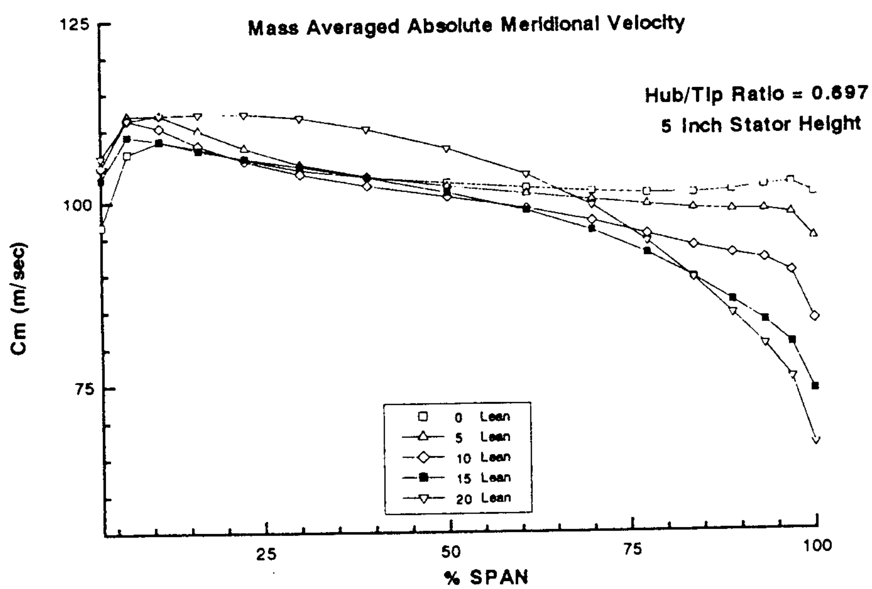

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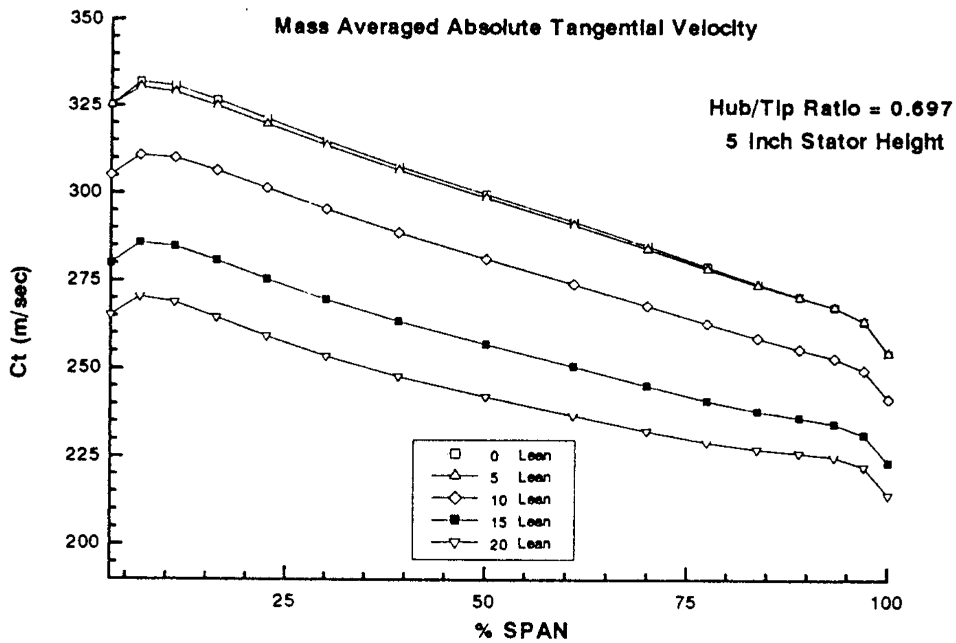

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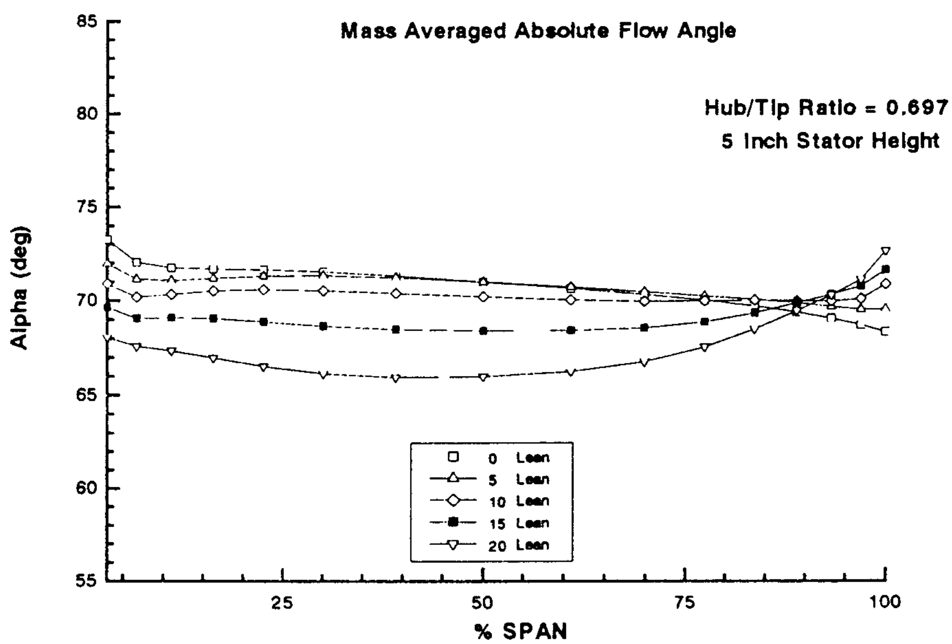

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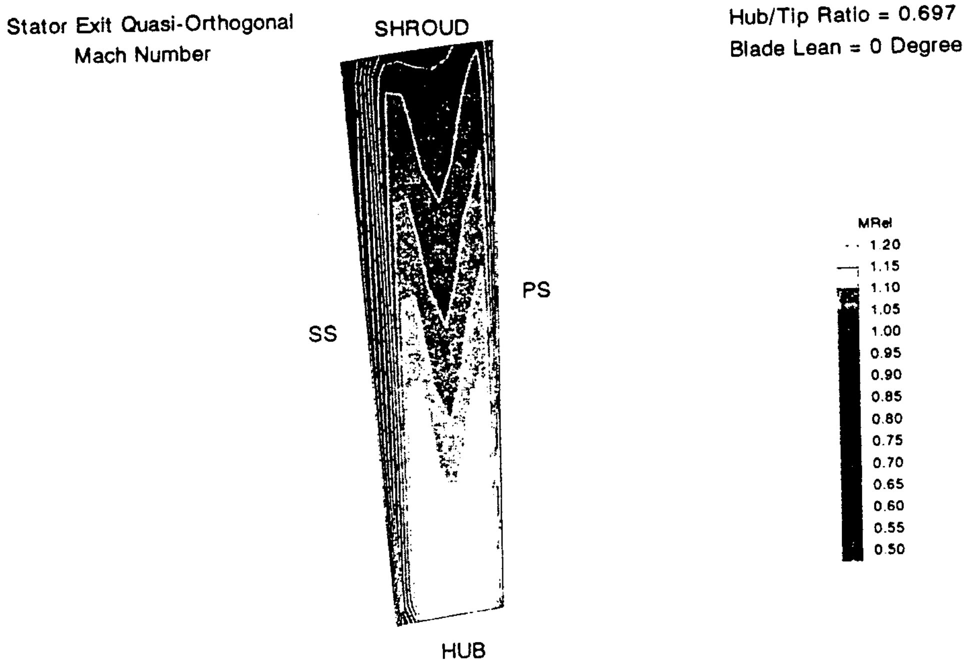

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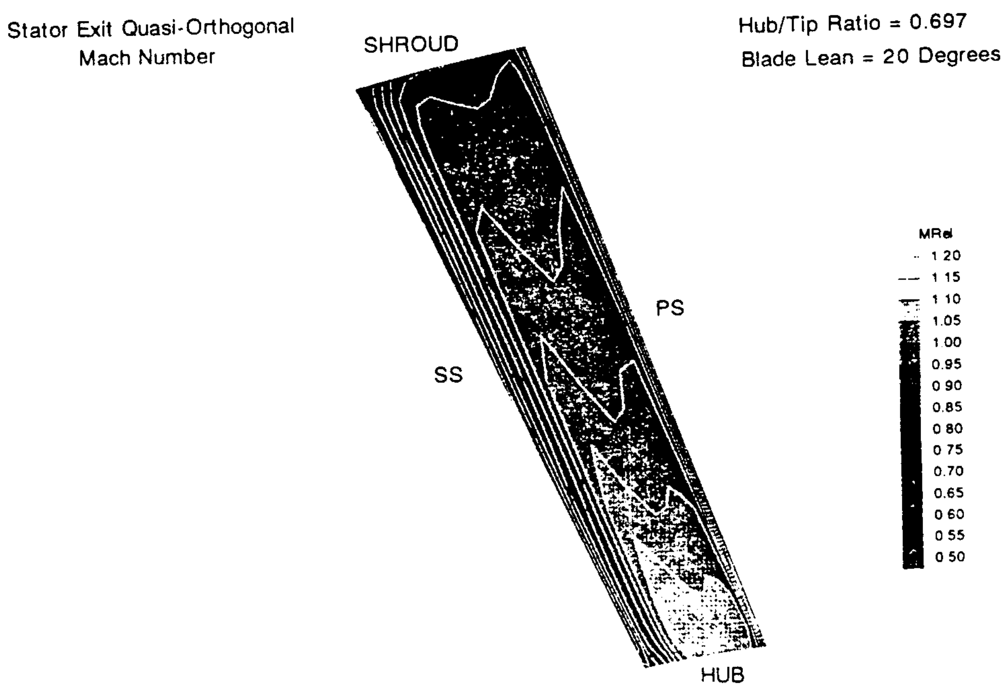

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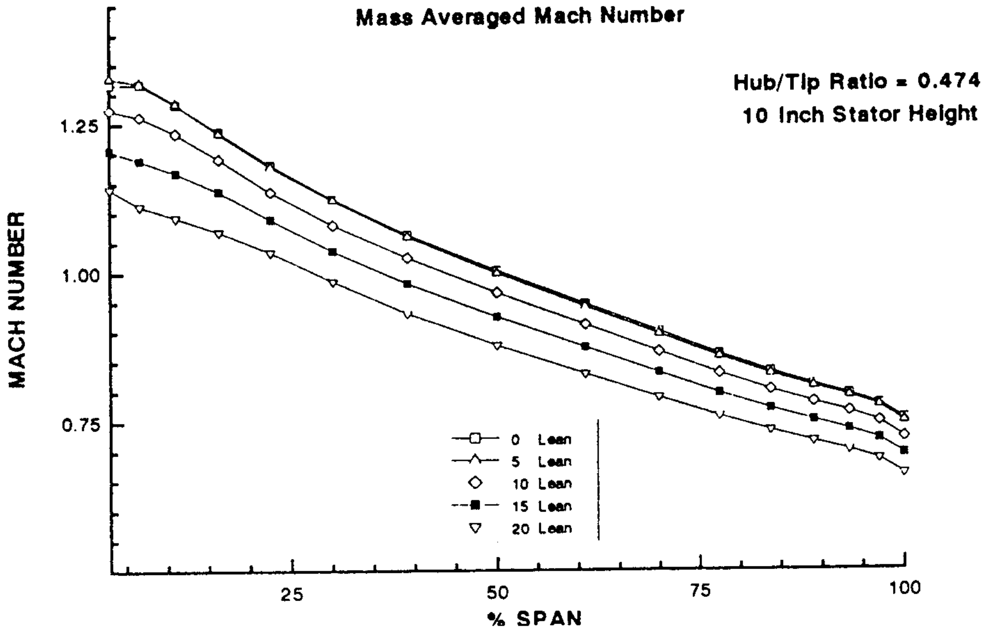

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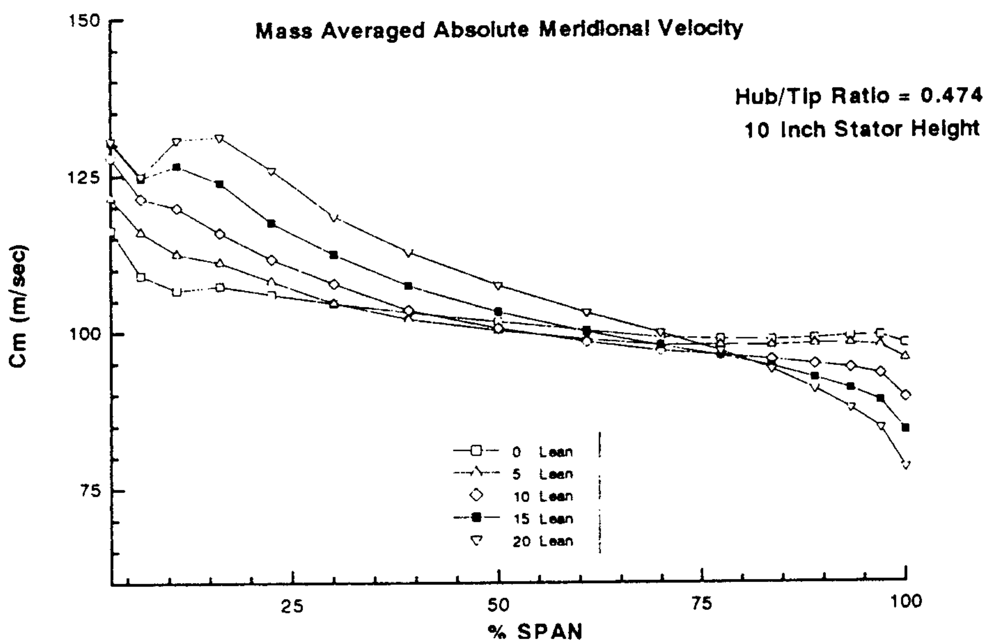

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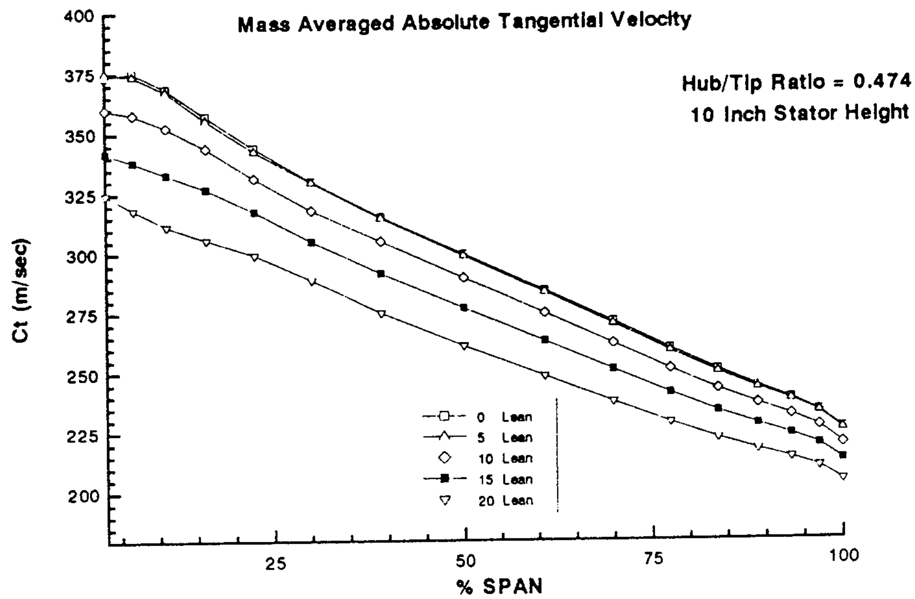

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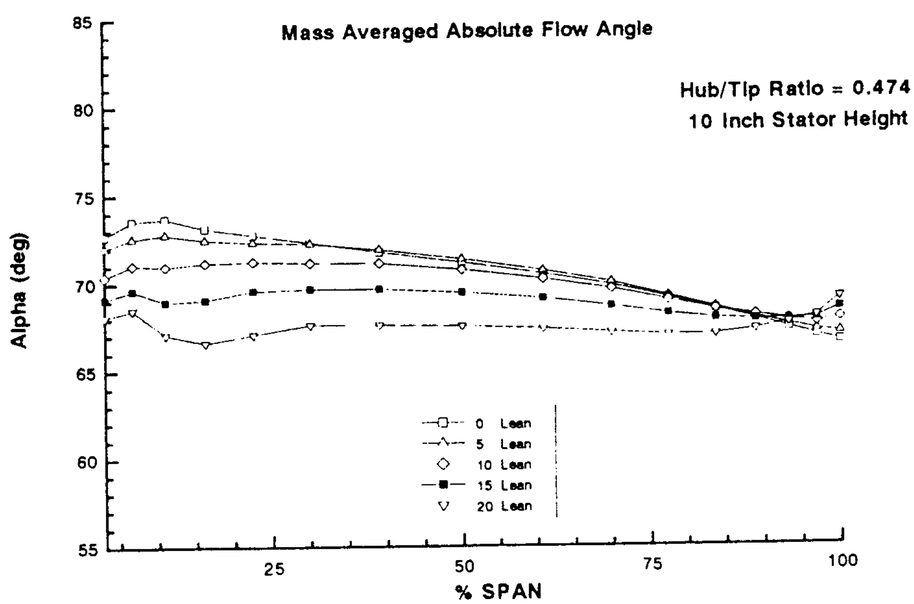

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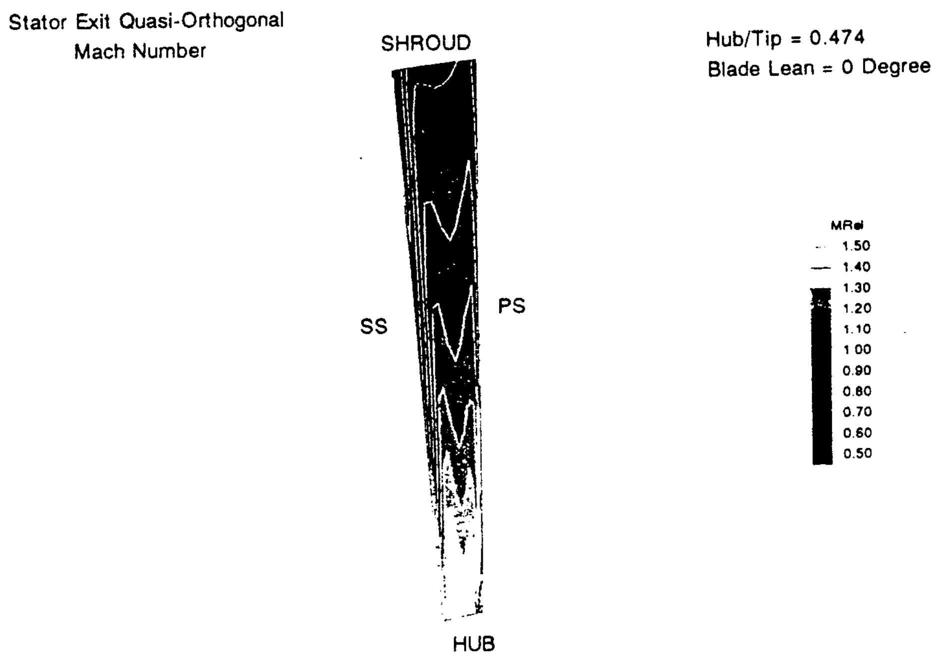

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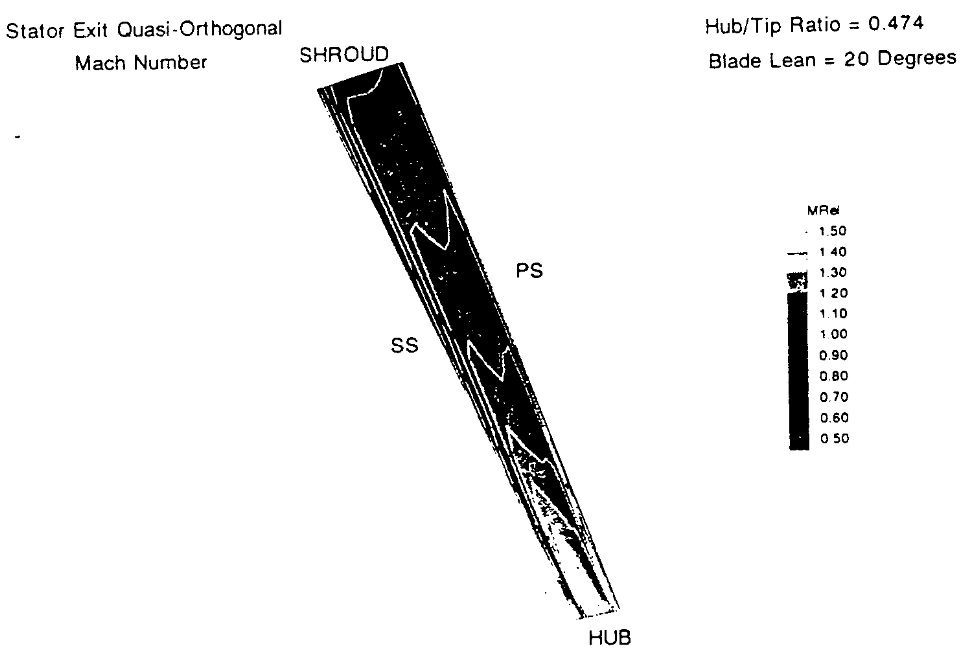

Figure 22

TABLE I

Blade Chord = 4.792 cm

Meanline Pitch = 2.9791 cm

Meanline Radius = 35.56 cm

Inlet Blade Angle = 0 degrees

Exit Blade Angle = 70 degrees

Inlet Total Pressure = 100, 000 Pascals

Inlet Total Temperature = 300 deg K

Ideal Gas Constant = 287.14 Joules/Kg deg K

K (Cp/Cv) = 1.4

Mass Flow of 0.931 Hub/Tip Ratio Stators = 3.933 Kg/sec.

Mass Flow of 0.697 Hub/Tip Ratio Stators = 19.79 Kg/sec.

Mass Flow of 0.474 Hub/tip Ratio Stators = 39.31 Kg/sec.

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